Description

Method and device for the combustion of fuel

The invention relates to a method and a device for the combustion of fuel in a combustion chamber.

The conventional method for converting fuel energy into heat is the oxidation or combustion of liquid fuel or gaseous fuel using an oxidizing agent such as atmospheric oxygen, for example. In the heavily loaded combustion systems of today, the problem exists in general that these systems must be configured for very low emissions, in particular for low NOx emissions. The combustion systems are expected to allow stable and complete combustion across the whole operating range, and function in a manner which requires comparatively little maintenance or expense. This problem is solved to some extent by known combustion systems which fall into three groups:

In so-called standard low-NOx systems, provision is made for fuel and combustion air to be premixed before entry into a combustion chamber. Inside the combustion chamber, a developing flame is then stabilized, thereby controlling the oxidation reaction. As a result of residual unmixed parts, high temperatures occur locally within the combustion chamber and can cause undesirably high NOx emissions. In the case of standard low-NOx systems, therefore, the flame is usually stabilized in a manner which is primarily aerodynamic, whereby hot combustion gases are recirculated such that they react with the mixture of fuel and combustion air which enters the combustion chamber. The aerodynamic stabilization is supported by the use of hot auxiliary flames (so-called piloting) which can also reduce the homogeneity of temperature distribution in

the combustion chamber. Such an inhomogeneous temperature distribution can represent an additional source for the occurrence of nitrogen oxides. In the case of standard low-NOx systems, therefore, it is standard practice to reduce the primarily occurring NOx emissions by catalytic cleaning of the exhaust gas.

The application area of catalytic combustion systems is currently limited, and therefore catalytic combustions cannot be used for e.g. high-temperature combustion systems such as the most recent type of stationary gas turbines, for example. Catalytic combustion systems are only used in smaller stationary gas turbines at present.

So-called flameless oxidation burners such as those described in EP 0 463 218 B1, for example, are known for industrial combustion systems. In these combustion systems, combustion air is preheated with the aid of the exhaust gas and supplied with significant impetus to a radial edge region of a combustion chamber. A combustion gas is injected separately in the center of the combustion chamber. The preheated combustion air mixes with recirculating exhaust gas in the edge region of the combustion chamber, and with the separately supplied combustion gas centrally.

The invention addresses the problem of producing a method and a device for the combustion of fuel in a combustion chamber, in particular for gas turbines, in which a stable and complete combustion as well as a clear reduction in NOx emissions are achieved.

According to the invention, the problem is solved by a method for the combustion of fuel in a combustion chamber, in which

fuel and combustion air are mixed (avoiding self-ignition) before entry into the combustion chamber, a first part of the mixture is introduced into the combustion chamber in such a way that it circulates in the combustion chamber, further fuel is added to the circulation flow of the first part of the mixture until heating up to ignition conditions is guaranteed, and at least one second part of the mixture is introduced into the combustion chamber in such a way that it mixes with a hot combustion gas which is flowing away from the circulation flow, heats up and combusts until its exit from the combustion chamber. The problem is further solved by a device for the combustion of fuel in a combustion chamber, comprising a mixing entity for mixing fuel and combustion air (avoiding self-ignition) before entry into the combustion chamber, a first mixture discharge entity for introducing a first part of the mixture into the combustion chamber in such a way that the first part of the mixture circulates in the combustion chamber, a fuel discharge entity for supplying further fuel into the circulation flow of the first part of the mixture until heating up to ignition conditions is guaranteed, and at least one second mixture discharge entity for introducing at least one second part of the mixture into the combustion chamber in such a way that said second part (of which there is at least one) of the mixture mixes with a hot combustion gas which is flowing away from the circulation flow, heats up and combusts until its exit from the combustion chamber.

According to the invention, a first volume of fuel (e.g. a combustion gas 1) is premixed with combustion air (avoiding self-ignition) before entry into the combustion chamber. In the subsequent reaction of parts of this mixture, a comparatively low temperature level is present, this being lower than the average temperature level of comparable combustion reactions.

The combustion of this part of the mixture therefore results in relatively limited NOx formation. According to the invention, the mixture of fuel and combustion air is introduced into the combustion chamber in such a way that a first part of the mixture circulates in a recirculation vortex and at least one second part of the mixture mixes with the hot exhaust gas or combustion gas which flows away from the vortex. As a result of the mixing with the hot exhaust gas, this part of the mixture is sufficiently heated and combusts until it reaches the combustion chamber exit. However, separate piloting in conventional form is avoided according to the invention, and it is likewise possible to dispense with aerodynamic stabilization measures using swirl generators.

As a result of adding the remaining fuel into the recirculation vortex in one stage or even in a plurality of stages (e.g. combustion gas 2) in accordance with the invention, a quantity of energy is provided such that heating of the entire air/fuel mixture to ignition conditions is guaranteed or until ignition conditions are present. According to the invention, the further fuel is added to the mixture in such a way that homogeneous mixing into the combustion gas occurs at a low temperature level. Temperature peaks within the combustion chamber are thus avoided according to the invention. The result is a particularly limited formation of NOx from this region of the reacting combustion gas flow.

In an advantageous development of the claimed method, the fuel and the combustion air are mixed before entry into the combustion chamber in such a way that the ratio of combustion air to fuel is higher than the average air/fuel ratio of the combustion in the combustion chamber. As a result of the high air/fuel ratio according to the invention, a comparatively low

temperature level is guaranteed, thereby reducing the formation of NOx.

The claimed device can be configured in a particularly advantageous manner if the first and/or second part of the mixture (and/or further parts in the case of a multistage fuel addition) of fuel and combustion air is introduced via a body which is arranged centrally in the combustion chamber. The first and/or second mixture discharge entity is arranged in such a central afflux body. In terms of flow, it is then relatively easy to implement, as intended by the invention, the circulation flow of the first part of the mixture and the discharge of the second part of the mixture into hot combustion gas which is flowing away.

Furthermore, a central afflux body for the first and/or second part of the mixture of fuel and combustion air advantageously offers the possibility of integrating an entity for discharging liquid fuel into the combustion chamber. A centrally arranged mixture discharge entity is moreover cooled by the mixture of fuel and combustion air which flows through it, whereby the mixture is minimally heated. The heating results in a further homogenization of the temperature level within the claimed circulation flow.

According to the invention, the circulation flow itself is advantageously formed in a peripheral region of the combustion chamber, i.e. in an outer radial section of the combustion chamber. A recirculation vortex thus formed advantageously provides the basis for mixing in further fuel into the combustion chamber in a maximally homogeneous manner.

According to the invention, it is moreover advantageous if the

combustion chamber is essentially cylindrical in shape and the first part of the mixture of fuel and combustion air is introduced into the combustion chamber in an essentially radial manner. As a result of the radial introduction of the first part of the mixture, the circulation flow as intended by the invention is stimulated and maintained. Alternatively, provision can be made for an annular combustion chamber and a correspondingly configured fuel supply.

In contrast with a radial introduction of the first part of the mixture of fuel and combustion air, the further fuel is advantageously introduced into the combustion chamber in an essentially axial manner. Such an addition of remaining fuel (combustion gas 2) into the recirculation vortex provides the quantity of energy that is required in order to ensure the desired heating up of the entire air/fuel mixture to ignition conditions. A further advantage of an axial introduction of the further fuel is that the supplied further fuel also contributes to a cooling of the combustion chamber end wall at the same time, whereby the further fuel is slightly preheated.

In order to configure the claimed device and the associated method in a comparatively simple manner, the first and the second part of the mixture of fuel and combustion air are advantageously discharged into the combustion chamber as a common stream which is only divided once it is inside the combustion chamber.

When introducing one or both parts of the mixture of fuel and combustion air, specially adapted nozzles can advantageously be used such that the relevant parts of the mixture enter the circulation flow in a particularly targeted and metered manner. In order to ensure that the claimed circulation flow and the

resulting combustion can be operated in a stable manner, approximately 5% to 25% (particularly between approximately 10% and 20%) of the total fuel and combustion air mass (total gas mass) which is supplied during one time unit is advantageously recirculated per time unit.

A preferred exemplary embodiment of the claimed method and the claimed device for the combustion of fuel in a combustion chamber is explained in greater detail below with reference to the attached schematic drawing, in which

- Fig. 1 shows a longitudinal section of an exemplary embodiment of a device according to the invention for the combustion of fuel in a combustion chamber.

A device 10 for the combustion of fuel in a combustion chamber is illustrated in Fig. 1 in the form of a burner for a stationary gas turbine. An essential component of the device 10 is a combustion chamber 12 which is essentially designed in the form of a circular cylinder along an axis 14. The combustion chamber 12 is formed to include a first end wall 16 which is shown at the top in Fig. 1, an outer wall 18 which extends downwards from said face wall, and a second face wall 20 which is shown at the bottom in Fig. 1.

A centrally arranged body 22, which essentially has the form of a circular cylinder and likewise extends along the axis 14, passes through the first face wall 16. The body 22 is configured to include an outer tube 24 and an inner tube 26 which is arranged concentrically therein. Nozzles 28 which are oriented radially outwards pass though the outer tube 24, and are located at the lower end region of the outer tube 24 with reference to Fig. 1. The outer tube 24 is otherwise closed at

this end region.

With reference to Fig. 1, provision is made for an air supply 30 (not shown in greater detail) at the upper end of the outer tube 24, and a combustion gas supply 32 (likewise not shown in greater detail) in the interior of the outer tube. Air and a first combustion gas are supplied via the air supply 30 and the combustion gas supply 32 respectively into the outer tube 24, in which a mixture 34 of combustion gas and combustion air then forms in a flow direction to the nozzles 28. A first part flow 36 of this mixture 34 issues from a part of the nozzles 28 into the surroundings of the outer tube 24 and therefore into the interior of the combustion chamber 12. A second part flow 38 of the mixture 34 issues via further nozzles 28', which are arranged further down on the outer tube 24 with reference to the above cited nozzles 28 of the first part flow 36 and with reference to Fig. 1.

The outer tube 24 is essentially surrounded by a recirculation space 40 which is adjacent to a further combustion space 42 within the combustion chamber 12. Flow guide surfaces 44 are arranged on the inside of the outer wall 18 between the recirculation space 40 and the further combustion space 42.

With the aid of these flow guide surfaces 44 and the discharge of the first part flow 36 (and the second part flow 38), said discharge being described in greater detail below, a circulation flow 46 is stimulated and stabilized within the recirculation space 40, said circulation flow initially being directed radially outward from the nozzles 28, then being directed towards the first end wall 16 and radially inwards along it, and finally arriving back at the nozzles 28 from the first end wall 16.

Provision is made for a further combustion gas supply 48 (not shown in greater detail) at the first end wall 16. Further combustion gas enters the circulation flow 46 via this further combustion gas supply 48.

Combustion gas 50 which is flowing away eventually leaves the circulation flow 46 in the region in front of the nozzles 28′ and passes through the further combustion space 42, arriving at an exit 52 which is formed in the end wall 20 as an essentially central opening. In an exemplary embodiment which is not shown, in which the combustion chamber is configured as an annular combustion chamber, this opening is annular.

During the operation of the device 10, a mixture 34 of combustion gas and combustion air is supplied to the nozzles 28 and 28′ by means of the outer tube 24, the air supply 30 and the combustion gas supply 32, wherein the ratio of air and combustion gas is higher than the average air/combustion gas ratio of the subsequent combustion within the combustion chamber 12. Self-ignition of the mixture 34 is avoided in this way.

The mixture 34 is introduced into the combustion chamber 12 in an essentially radial manner as a first part flow 36 and a second part flow 38. In this case, the nozzles 28 are arranged and shaped in such a way that the first part flow 36 essentially enters the circulation flow 46 and thus stimulates a recirculation vortex within the recirculation space. By adding further combustion gas via the further combustion gas supply 48 in an essentially axial direction, the recirculation vortex is additionally supported such that significant energy is provided, thereby in principle ensuring a heating up of the

entire mixture to ignition conditions.

The quantity of gas admixed to the mixture per time unit at the further combustion gas supply 48 is such that maximally homogeneous mixing occurs in the recirculation vortex and temperature peaks are avoided. The mixing in takes place at a comparatively low temperature level such that, although there is a reaction of the combustion gas with the combustion air, this reaction only results in very limited NOx emissions. Moreover, the combustion gas supply 48 contributes to the cooling of the first end wall 16 of the combustion chamber 12.

Within a stable circulation flow 46, of the total mass of combustion air and combustion gas which is supplied during one time unit, approximately 10% to 20% flows per time unit. This total gas mass is preheated in the recirculation vortex. The resulting combustion or reaction of the mixture 34 occurs in the context of a gas which has been thoroughly mixed and is particularly homogeneous, and at a comparatively low temperature level avoiding temperature peaks. It is therefore possible to dispense with separate piloting in conventional form and with aerodynamic stabilization measures using swirl generators in the combustion chamber 12. A further main advantage of the combustion chamber 12 and the associated two-stage supply of combustion gas in the recirculation space 40 is that catalytic converters are not necessary.

The second part flow 38 (and optionally further part flows) of the mixture 34 enters the combustion gas 50, which is flowing away, directly via the nozzles 28', said nozzles being configured e.g. as small tubes, or can likewise wholly or partly recirculate in the case of an exemplary embodiment which is not shown. The combustion gas 50 which is flowing away is

comparatively hot, and therefore the second part flow 38 heats up sufficiently and likewise reacts completely as far as the exit 52.

Finally, it should be noted that the centrally arranged body 22 and the inner tube 26 which is configured therein offers the possibility of integrating liquid fuel nozzles, and therefore the device 10 overall can be used as a dual-fuel system. Therefore the device 10 also allows liquid fuel to be oxidized in a manner which produces comparatively few pollutants, whereas this was not previously possible in the case of conventional systems using catalytic converters.